633

VOLUME 81 SEPARATE No. 633

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

FEBRUARY, 1955

SCOPE OF PIPELINE TRANSPORTATION IN THE UNITED STATES

by Eldon V. Hunt, M. ASCE

CONSTRUCTION DIVISION

{Discussions open until June 1, 1955}

Copyright 1955 by the AMERICAN SOCIETY OF CIVIL ENGINEERS
Printed in the United States of America

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

PRICE $0.50

THIS PAPER

--represents an effort by the Society to deliver technical data direct from the author to the reader with the greatest possible speed. To this end, it has had none of the usual editing required in more formal publication procedures.

Readers are invited to submit discussion applying to current papers. For this paper the final date on which a discussion should reach the Manager of Technical Publications appears on the front cover.

Those who are planning papers or discussions for "Proceedings" will expedite Division and Committee action measurably by first studying "Publication Procedure for Technical Papers" (Proceedings — Separate No. 290). For free copies of this Separate—describing style, content, and format—address the Manager, Technical Publications, ASCE.

Reprints from this publication may be made on condition that the full title of paper, name of author, page reference, and date of publication by the Society are given.

The Society is not responsible for any statement made or opinion expressed in its publications.

This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

0.50 PER COPY

SCOPE OF PIPELINE TRANSPORTATION IN THE UNITED STATES

Eldon V. Hunt,[1] M. ASCE

INTRODUCTION

There is a pipeline, either for crude oil, petroleum products or for natural gas in or across all or part of every state in our country. This transportation network has a mileage of more than 594 thousand miles and includes the mileage of pipes in the distribution systems of towns and cities but does not include service lines or pipe devoted to water, drainage or sewage lines. Of the three types of pipelines, the crude oil lines have the longest history in the United States but it is of historical interest to note that the ancient Chinese transported natural gas through bamboo pipes considerable distances for the purpose of evaporating water from brine to obtain salt.

They are a vital factor in the economic life of the nation and influence planning for our national defense.

They affect the land from which the oil or gas comes, the lands over which they traverse, the industries they serve and the industries that mine, produce and fabricate the steel with which they are made and maintained. They are a part of the investments of millions of life insurance policies and they exert a personal influence on the individual lives of nearly every person in the country.

The development and expansion of the pipeline systems of this country are of contemporary times and their trend is continued growth and importance.

Development of Oil and Products Lines

The first impetus for pipeline construction had its origin in the discovery of oil by Colonel Drake at Oil City, Pennsylvania in 1859. The Drake initiated boom occurred along Oil Creek in very rough terrain and was several miles from a railroad. The oil was hauled in barrels by wagons and teams to the railroads at a cost of from three to five dollars a barrel for a haul of about twenty five miles. Within a year this oil cartage grew into a huge, fiercely competitive business employing several thousand teamsters.

In 1861 an attempt was made to build a pipeline of wooden pipe to carry this oil. The venture was abandoned when the irate teamsters dug up the pipe at night which had been laid during the day and when fighting and bloodshed occurred. Four years later however, Samuel Van Sychel built the first crude oil line from Pithole City to Millers Farm in western Pennsylvania. It was of wrought iron, two inches in diameter and was five miles long. It had a capacity of approximately 800 barrels a day and operated at a pressure of about 200 psi, the motive power being furnished by three steam driven pumps in two stations. This capacity was equal to about 300 teams of horses working ten hours per day. During the construction of this line two crews

1. Chf. Engr., Alberta Gas Trunk Line, Ltd., Calgary, Alta., Canada

were used, one to stand guard over the finished work to prevent its destruction by the angry teamsters and the other crew to do the work by day!

At first the railroads were pleased to see this new industry, for it gave them revenue from hauling pipe, but before long they realized what was happening. Here was competition and they were not inclined to accept it. They fought the building of other pipelines by every means available and formed powerful lobbies with the teamsters and barge companies. They refused to allow pipelines to go under their tracks and it is reported that on one occasion a locomotive was used to pull out a pipeline which had been laid parallel to the tracks. But the economics of pipeline transportation for oil proved to be too strongly supported to prevent its development by violent or legal means.

In 1874 a sixty mile, four inch line was built into Pittsburg by a Dr. Hostetter, who was a patent-medicine manufacturer. (Crude oil was sold in bottles at prices of from fifty cents to a dollar for a half pint and was purported to be a cure for almost any ailment). In 1879 a six inch crude line of wrought iron pipe, using thread connected couplings was built from Coryville to Williamsport, Pennsylvania and was later extended to Bayonne, New Jersey. By 1900 there were approximately 18,000 miles of crude oil pipelines of different sizes and lengths fanning out in all directions from the Pennsylvania fields.

In 1901 the famous Lucas gusher in the fabulous Spindletop Field of Texas was brought in and with it there was created another pipeline situation and one which was of a vastly different magnitude. Up to this time the crude lines had been confined for the most part to the Pennsylvania Fields and adjacent refineries. But this new oil field and the fields subsequently 'brought in' were 1500 miles from the consuming markets of the Chicago Area and the Eastern Seaboard. It was only natural therefore that the first trunk lines were to spread out from the Texas fields to the tidewater where the oil could then be moved by tanker to the Eastern markets.

The Kern river fields of California also came in about this same time and the Standard Oil Company built an eight inch line three hundred miles long to San Francisco and in 1904 a 100 mile six inch line was built into Monterey to carry crude oil. Because of the density of this California crude, a great deal of difficulty was encountered in pumping it through these lines, and finally in 1906, the Southern Pacific Company developed a 'Rifled Pipeline' which helped to solve this problem. The method was to "rifle" the pipe, making its interior appearance similar to that of a rifle barrel. A small percentage of water was pumped into the line with the oil. The rifling of the pipe causes the whole mass to 'whirl' and as the water is heavier than the oil it was thrown to the exterior of the mass, thus causing the envelopment of the oil with a thin shell or film of water, which acted as a lubricant.

Products lines had their beginning about 1901 when two four inch lines, originally built to carry crude oil from Titusville to Wilkes Barre in Pennsylvania were converted for the transportation of kerosene. By 1930 the total mileage of pipelines devoted to the movement of products was only 1300 miles but since then their growth has been very rapid until today there are about 24,000 miles of lines carrying petroleum products.

In 1910 there were approximately 40,000 miles of crude oil and product lines. At the start of World War II the total had increased to approximately 125,000 miles. Because of the vulnerability of tankers to Nazi submarine attacks, the Big and Little Inch lines were rushed through as a wartime measure. These, together with recent additions, have brought the present total to about 170,000 miles of crude oil and product pipe lines in service.

It is interesting to note how the products lines maintain the identity of the individual consignments which are being moved through the line. Frequently a line will contain many batches along its length which differ as to type, grade and ownership. One long line has had as many as 65 different batches moving along at one time. These products are simply introduced into the line one behind the other and each pushes along the batch ahead. The amount of mixing is negligible and what little there is, is blended into other shipments in such quantities as not to affect them. It is essential to know the location of the faces of these batches at all times, especially since the products move at about four miles per hour which means the quantity or slug which has intermixed would pass the valves at a station in the matter of few moments. Valve operations must be timed to a few seconds to keep the products separated and 'switched' into their proper tanks. It has been found that the introduction of minute quantities of radioactive isotopes at the beginning of a shipment gives the pipeline an accurate location of that shipment through the use of radiation counters located at appropriate points along the line.

Economies of Oil and Products Lines

The advantage pipelines have over any other means of transportation for the movement of fluid products can quickly be understood when one realizes that with a pipeline there are no empty vehicles to return and no cars to build or service. Fluids present no problem as to size or shape and require no packaging or crating. There is no waste power. Delivery is continuous and the amounts to be delivered can be predicted accurately. The system is below the ground, out of the way and is free from most of the maintenance problems of surface transportation. Theft is almost impossible and there are no traffic accidents. The labor required for operations is small. When we compare the cost of moving barrels of oil by team and wagon in the early days, which was from three to five dollars a barrel, to the cost of approximately five cents a barrel for electricity for pumping oil a distance of over a thousand miles, the economics of pipelines for oil and products transportation is quite apparent and shows the great strides the industry has made.

The industry is characterized by high capital costs and low operating expenses. The average per mile investment in oil and products lines is about ninety seven thousand dollars whereas the railroads have an approximate per mile investment of about one hundred thirty five thousand dollars. These figures are given for the purpose of a comparison only since they have no other relationship. There are about 27 thousand persons employed by the oil and products lines. The average annual salary per person is in excess of $4,300.00 per year.

Each year in the United States about 2-1/2 billion barrels of oil are moved from a half million producing wells through some 350 refineries and the resultant products distributed throughout the nation. A large portion of this transportation is done by the oil and products pipelines and amounted to well over 100 billion ton miles last year. Nearly twenty five hundred pumping stations furnished the motive power for this movement. In 1950 the railways hauled 58.5 percent, trucks 12.5 percent, Great Lakes shipping 11.1 percent and oil pipelines 12.8 percent of the ton miles of all freight traffic transported in the United States. These oil and products pipelines constitute but one fourth of the total pipeline mileage of the country. To further illustrate the economic advantage pipelines have for transport of fluid products, there are about 103 thousand tank cars in the country devoted to the movement of petroleum

products. These cars run up an annual mileage of more than 2-1/4 billion miles—half of which is for the return of the empty cars.

Pumping Stations on Oil and Products Lines

The early pumping stations on crude oil and products lines used steam as power. The horizontal air-injection oil engine was next, only to be followed by the vertical diesels of larger horsepower and greater efficiencies. Among the early pumps was the Dow duplex, outside packed plunger, with a capacity of about 6,000 barrels per day against a pressure of 1,000 pounds. Today some of the largest pumps in oil line service are two 6,000 hp steam turbine driven centrifugal units on the Arabian American Oil Company line. Either pump can deliver full line throughput—as much as 400,000 barrels daily at 800 psi discharge pressure.

The trend on these lines is strongly toward electric drive in pumping stations using power supplied by the electric utility companies. This has come about by the broad extension of electric power during the past ten years which has made electricity available even in remote areas. The electric motor drive has one distinct advantage, and that is its adaptability to automatic and remote controls. The electric powered stations have the additional advantage of requiring much less manpower to operate and maintain.

Development of Natural Gas Pipelines

In 1821 at Fredonia, New York, natural gas was first piped from shallow wells to several homes in the vicinity where it was used for illumination. In 1825 while on a visit to the United States, General Lafayette arrived by stage coach at the old Taylor House in Fredonia at night and found the place brilliantly illuminated in his honor by this natural gas. The Fredonia Gas Light and Water Works Company was formed in 1865 to become the first company organized to engage in the natural gas business in the United States.

It is of interest to note that George Washington became a part owner in a natural gas field in 1776. He wrote of a "tract of which 123 acres is a moiety (half interest) and which was taken by General Andrew Lewis and myself for and on account of, a bituminous spring which it contains, of so inflammable a nature as to burst forth as freely as spirits and is nearly as difficult to extinguish." This 'burning spring' was on the banks of the Kanawha River near Charleston, West Virginia in what was later to become the first great natural gas producing region.

It has been only in the past few decades that natural gas has had any but local significance as a source of energy. The principal explanation is that there was no feasible way to transport the gas before the advent of suitable pipe, particularly steel pipe. This restricted the use of natural gas to domestic and local uses and such manufacturing processes oriented to the fuel source rather than to the market.

The use of gas for illuminating purposes had been known for a long time however, going back as far as 1691 when coal gas was used for this purpose in Ireland. The invention of the 'gas chimney' by Armond in 1784 improved the lighting qualities of this gas and in 1803 Baltimore had gas lights. By 1812 there were some 120 miles of mains in London with Westminster Abbey being gas lighted in 1814.

Pipe has been the dominant factor in the development of gas pipelines. The cast iron pipe which was first used left much to be desired although it is still

used in low pressure lines today. Wrought iron pipe came into use about 1830 and was much lighter and tougher than cast and made possible the screw joint and thereby reduced the amount of leakage in gas transmission. About 1871 an attempt was made to construct a gas line from West Bloomfield, New York to Rochester using pipe made of pine logs which had been bored with eight inch holes. This line was a failure. In 1872 about six miles of two inch iron pipe was laid between Newton Wells and Titusville, Pennsylvania but the high pressures and greater capacities of gas lines did not begin until about 1891 when Solomon R. Dresser, a manufacturer of oil well equipment, developed a flexible and leak-proof joint which bears his name.

To prove the worth and advantage of his coupling, Mr. Dresser built, at his own expense a five inch line several miles long from a gas field into the town of Malta, Ohio, this line becoming the first successful gas-tight or leak-proof gas line in the country. A second line using Dresser couplings was laid in 1896 by the United Natural Gas Company to bring gas to Buffalo through a twelve inch line and the third Dresser line was built into Pittsburgh in 1898. The East Ohio Gas Company built a line from the West Virginia fields to the industrial area of north central Ohio in 1899. In the same year a ten inch line one hundred miles long and using Dresser couplings brought gas from Sugar Grove in Central Ohio to Toledo for the purpose of serving the glass industry there. Until the late 1920's the transmission of natural gas had been developed in a limited way in the Southwest and Appalachian areas to supply gas to cities and industries which were comparatively near-by. In the late 1920's and early 1930's, rapid expansion started with pipe-lines being built to New Orleans, Memphis, Chicago, St Louis, Denver, Atlanta, San Francisco and Los Angeles, the manufactured gas facilities being converted to distribute natural gas. There was a lull during the de-pression days, following which natural gas has been supplied to practically all of the United States with the exception of the Northwest. In addition, large pipelines have been built from Texas to California to supplement their local production. It is well known that an argument is now on as to who shall supply the Northwest markets. Natural gas lines have spread out from producing fields until at the end of 1952 the combined network of field and gathering, transmission and distribution lines operated by the gas utility and gas pipeline industry aggregate more than 424 thousand miles of all size pipe. By way of comparison, on December 31, 1952 there were 375,296 miles of railroad trackage owned and operated by the railroads of the United States.

Throughout the years the sizes of pipe have gradually increased until today the 30 inch line is considered commonplace and we find a considerable amount of work being done by pipe manufacturers and equipment companies to develop a 36 inch steel pipe and the methods and means to handle it on cross country lines.

The aggregate consumption of energy in the United States during 1952 was 38,773 trillion Btu. Our annual energy consumption has gained 391 percent during the course of the century and forty two percent since 1941. In the prewar decade coal contributed 54.9 percent of this total, petroleum 30.7 and natural gas 10.6 percent. During 1952 the distribution was 34.0 percent for coal, 39.4 percent for petroleum and 22.5 percent for natural gas. Natural gas now heats almost as many homes as are heated by coal and furnishes about 20 percent of the fuel consumed by the electric utility industry. To move this natural gas, approximately 7-1/2 trillion cubic feet and equivalent to about 31 and a quarter million tons of bituminous coal, the gas pipelines have about 6-1/2 million compressor station horsepower installed in their

compressor stations. This total horsepower is the equivalent to the horsepower which could be developed by about 4,700 diesel electric railroad locomotives.

During the four years from 1953 through 1956 the gas utility and pipeline industry plan to spend almost four billion dollars for construction of new facilities and expansion of present plant. About 1.9 billion will be spent on transmission facilities; 1.4 billion on distribution and about 637 million on production, underground storage and general facilities. Since 1945 the natural gas pipelines have used nearly twelve million tons of steel in their line pipe.

Compressor Stations

Gas compressor stations have undergone a marked change with the passing of time. The very early stations used steam since it was the only type of power then available. Steam is being used again in turbines to furnish power for centrifugal compressors several gas pipelines have recently installed. The most of this work is done however with reciprocating gas engine units which range in size from 500 hp to the giants developing 2,400 hp. Compressor stations are spaced at about eighty mile intervals and it has been found that additional stations giving frequent but smaller pressure boosts are the most economical.

One of the new developments is the gas turbine which has already shown promise of great things in the transmission of gas. The first installation of this type was made in 1949 when an 1,800 hp unit was placed into operation at a compressor station in Arkansas. This was the first commercial gas turbine in the United States to burn natural gas and the first installation in the world of a gas turbine power plant driving a centrifugal compressor for natural gas transmission.

The Texas Eastern line has twenty compressor stations equipped with single-stage centrifugal compressors, each directly connected to an electric motor. These stations range in size from 3,750 to 19,000 hp and constitute 221,250 hp of the total installed compressor station power of the 357,410 hp now on this pipeline.

Pipeline Communications (All types of lines)

A well operated and efficient communication system is essential to the successful operation of any pipeline. In the earlier days, parallel telegraph and telephone lines were built for dispatching purposes and general communication uses. Telephone booths were placed at regular intervals along a line to which the linewalkers had access for the purpose of reporting any leaks or other troubles located by them on their long walks. Hourly gauge or pressure reports were sent by the field locations to the central dispatching offices and the lines were regulated from these reports.

Since communications are so essential to pipelines, it was only natural that they would be among the first of the industries to adopt radio and microwave facilities for their dispatching, message transmission and remote control of station operations. By the use of remote controls and electric pumps and compressors a line becomes almost automatic in its operation and an oil line in Ohio is now being remotely controlled by the dispatcher in New York City.

Storage Facilities (All types of lines)

The storage of pipeline deliveries at the terminal end of a line is a problem which both fluid and gas pipeline operators have in common. Fluid products are stored in large tanks in the familiar oil company 'tank farms' and their only limit is tank capacity. But gas volumes are too great to store in tanks in sufficient quantity to take up the slack between the necessary economical uniform flow and the seasonal and industrial demand. This problem has been neatly solved in a number of cases through the use of exhausted gas and oil fields and salt domes near areas of consumption. Abandoned quarries have also been studied for this purpose.

At the beginning of the 1952-53 heating season about 700 billion cubic feet of natural gas was in underground storage. It would take about forty thousand of the largest size gas holders to handle this volume.

The crude oil trunk and gathering lines have a pipeline 'fill' of about fifty million barrels which represented about 18 percent of the crude petroleum in storage as of December 31, 1952. The corresponding 'fill' of the products lines is nearly 10 million barrels which is equal to about 4 percent of the stock total of all light products. There are no accurate figures available to show the amount of gas in the 'fill' of gas lines but it runs into billions of cubic feet.

Influence of Pipelines on Property and Business

That pipelines exert an influence on the lands over which they have a right-of-way is well illustrated by the rights-of-way problems encountered on the recently completed 154 mile gas pipeline which the writer supervised as Construction Superintendent and which was built for the South Carolina Natural Gas Company. This line began at Aiken, South Carolina and went to Columbia and Charleston, South Carolina. It crossed seven hundred and fifty different tracts of land. An abstract of ownerships going back more than twenty-five years was made on each tract. Local attorneys were employed for this work of making title searches. Defective titles were cleared before easements could be executed. Estates which had been divided years before but not legally settled were settled, guardians were appointed by the courts for minor heirs and for those who were mentally or otherwise incompetent. Non-resident owners were contacted either by right-of-way agents or by attorneys living in their towns and signatures obtained on whatever document that required the signature. Consent to construct the line and to enter upon the properties were obtained from all tenants. Disputed land lines were surveyed by licensed surveyors and re-established to the satisfaction of the adjoining owners and the owner. Subordination of all liens was obtained from those who held the mortgages or rights. All executed easements and damage releases were recorded at the respective county court houses.

Upon completion of the construction, each owner and tenant was contacted again and a settlement made to cover any construction damage he might have sustained. When the work was all done more than three thousand documents were in the records to cover the land grants for this 150 miles of pipeline.

In order to accomplish this work the field agents drove nearly 250 thousand miles calling on land owners over the space of about seven months. These land owners were paid the standard rate of one dollar per rod for the easement rights. Add to these payments the money paid for the settlement of construction damages and the total is in excess of a quarter million dollars

for the land rights for this line. This money was felt and appreciated in the various communities along the line.

In 1953 pipelines, oil and gas, used more than 3-1/2 millions of tons of line pipe, most of which went into new construction. This new construction means additional property values on which taxes can be collected for schools, roads and other public improvements. The life insurance companies of the country have invested more than one and a half billion dollars in pipeline securities compared to about 14 billions they have invested in other public utilities.

Pipeline Construction Materials and Methods

As stated before pipe has perhaps been the primary factor in the development and expansion of our pipeline systems. Cast and wrought iron pipes were not as adaptable as steel pipe for cross country lines although both of these types of pipe have their special qualities and their present day uses in the industry.

The progress made in steel pipe manufacture was prompted by the economics of bigger size and higher working pressures. For an example of this the per barrel-mile costs on a 20 or 24 inch oil line running at full load are about 40 and 36 percent respectively of the equivalent full load costs on a ten inch line in the same territory.

The advent of the Dresser coupling helped to make the use of bigger pipe possible because it provided a gas tight joint which also possessed some degree of flexibility. This coupling, which consists of a center ring or sleeve into which the two joints of pipe fit and two follower rings containing equally spaced bolt holes, has a special rubber gasket which is expanded against the sides of the pipe and center ring when the bolts are tightened thus making a gas-tight joint or coupling. This coupling or center ring has a tolerance which allows a deflection of a degree or more per joint thus reducing the necessity for bending the pipe itself.

Oxy-acetylene welding came into being about 1920 and more or less displaced the Dresser coupling for cross country pipelines although this coupling is still widely used in distribution systems and other installations today. By 1928 the electric arc welding process displaced the oxy-acetylene welding and is the process which is universal today in pipeline construction. During this period the sizes and strengths of pipe steadily increased. In 1936 only one fourth of the crude lines were larger than 8 inches but today most of the crude lines are in excess of ten inches in diameter and more than five thousand miles are above 12 inches. The recently completed Lake Head Pipeline is 30 inch pipe and the largest gas lines are 34 inch.

The development of X-ray and radioactive methods of inspecting metal has greatly improved the quality of welding done today and of course has had an influence on the developments of these lines.

Pipe lengths have increased from the early ten foot joints of cast pipe to the forty foot joints of 30 inch and larger steel pipe of today. Some of the smaller sized pipes come in joints up to sixty feet in length. This increase in length of joints has speeded up construction and lowered construction costs correspondingly. One of the systems widely used is 'double jointing' or the welding together of two joints of pipe at yards or storage areas and moving these double length pieces of pipe to the line as a unit instead of as single joints.

Construction machinery and equipment has kept pace with other developments or perhaps has made possible the development of the long joints of

pipe. A forty foot joint of 30 inch pipe weighs up to 2 1/2 tons. This weight could not be man-handled into ditch as the pipe was handled during the pioneer days of pipelining. The most spectacular of any of the machines devoted to pipeline construction is the famous 'side boom' tractor which was developed by pipeliners and is almost the universal symbol of the industry. Legend has it the first side boom was an improvised gadget made on the job by a 'lazy foreman' of a pipe gang.

The modern ditching or trenching machine can excavate a trench four feet wide and from five to seven feet deep and do this at the rate of a mile and a half a day depending upon the type of soil and amount of rock encountered in the ditch line. Customary pipeline specifications call for a minimum cover of thirty inches over the top of a pipe so that a thirty inch line will require a ditch five feet deep minimum. For every mile of such line approximately 3,900 cubic yards of excavation is piled up on the bank and then moved back into the ditch after the pipe has been lowered in.

In the early days bending was done by snubbing the pipe to a large tree or post and bending it with whatever power was available, mostly man and mule-power. Large diameter pipe was placed on a pair of supports and a fire was built under the middle of the joint to make the bend. Specifications in some of the contracts prescribed a cherry red color before bending and certain conditions for cooling it after the bend had been made. Today a specially designed bending machine can make smooth bends in pipe up to 36 inches in diameter without heating the pipe or disturbing the wall thickness. These machines are hydraulically operated, power being furnished by a small gasoline engine.

The machines that clean, coat and wrap pipe with protective asbestos and fibre glass wrapper are a specialty of the industry. In the olden days of pipelines this work was done by hand and many a mile of line has been flood coated and 'granny ragged.'

Each river crossing regardless of the size of the pipe constitutes a separate and special engineering problem and it is not within the scope of this paper to discuss this challenging phase of pipelining. It is appropriate however to mention the latest and perhaps most heroic crossing—that of the Lakehead line crossing the Mackinac Straights. A number of interesting papers have been written about this crossing.

CONCLUSION

Pipelines are an important segment of the economic life of this country. Gas and oil have become a necessity for our way of living. We rely on them for heating our houses and cooking our meals, to run our automobiles and as a raw material for a vast number of petrochemicals. A great amount of thought is now being given to ways of assuring their supply in the event of another war.

Those engaged in the industry will continue their study and work on corrosion control, the development of new and better pipe and welding processes; methods to increase the efficiency of lines and motive power; better maintenance and operating practices and further economies in construction.

Additional reserves of both oil and gas are continuously being discovered and developed. So long as this continues, additional pipelines will be required to transport them. This industry offers a broad horizon to young men with vision and enterprise and their success will be measured by the contributions

they make to it. We who have been in the industry can look back upon the achievements of this great industry with pride and can feel it has been to our honor to have had a part in this development.

BIBLIOGRAPHY

Articles

"Chronology of the Natural Gas Industry "- American Gas Journal, May 1950 by Louis Hilt.

"Rifled pipes for conducting heavy crude oil "- Illustrated Science—American Science, September 15, 1906 by J.O.Isaacs.

"100 Mile Oil Pumping Line" – Journal of Electricity, January 1905.

"Lake Head Pipe Line Now In Operation"—Pipe Line News, February 1954.

"Excavating Machinery for Ditching and Trenching "- Engineering News, February 23, 1911 by Tratman, E.E.R.(Assoc M.ASCE)

"Oil Pipe Lines in California"—Engineering News, March 13, 1913 by B. K. Stroud.

"Building a 375 Mile Pipeline in 193 Calendar Days "- Engineering News, Record, Oct. 4, 1928 by Wm Thompson Smith.

"Pipelines Laid in English Channel Carried Gas and Oil to France"—Engineering News Record, June 7, 1945.

"Oil Pipeline"—Mechanical Engineering, March 1952.

"Coal Pipeline"—Mechanical Engineering, March 1952.

"Paper Pulp Transported Through Pipeline"—Engineering News Record, November 1, 1928.

"Resistance to Flow of Molasses Found to Agree with Basic Laws"—Engineering News Record, Oct. 12, 1933 by Glen N. Cox.

"Motor Driven Centrifugal Pumps in Oil Pipeline Service"—Engineering News Record, March 1, 1928.

"Cast Iron Pipe Prices in Boston from 1868 to 1917"—Engineering News Record, May 9, 1918.

"Reducing Cost of Bending Pipe"—Engineering News Record, Oct. 31, 1918.

"Concrete Oil Reservoir Fails"—Engineering News Record, Feb. 23, 1911.

Unpublished Material

American Iron and Steel Institute, Facts and Figures on Steel Production.

Ebasco Services Incorporated, Miscellaneous Construction Records.

Institute of Life Insurance, Life Insurance Data.

Dresser Manufacturing Company, Historical Data.

Trans-continental Gas Pipeline Corporation, Right-of-Way Data.

South Carolina Natural Gas Company, Right-of-Way Data.

Reports

American Gas Association, Gas Facts—1952, New York 1953.

American Petroleum Institute, Petroleum Facts and Figures, Tenth Edition 1952, New York 1952.

Gas Appliance Manufacturers Association Inc., Natural Gas Construction Data July 1, 1945—Jan. 1, 1953 New York 1953.

Association of American Railroads—Railroad Transportation 1911—1951, Washington D. C. March 1953.

Institute of Life Insurance—Insurance Fact Book 1952 New York 1953.

Public Documents

U. S. Bureau of Mines, Information Circular 7671 Washington, Department of the Interior, November 1953.

U. S. Bureau of Transport Economics and Statistics, Sixty Fourth Annual Report on the Statistics of Railways in the United States for the year ended Dec. 31, 1950, Washington, D. C., Interstate Commerce Commission 1952.

Bituminous Coal Institute, 1952 Bituminous Coal Annual, Pittsburgh, Bituminous Coal Institute 1953.

2090
2870
512
4607
783
5711
1053
6055
7541
7556
110
2206
4828
32,522
14,733
44,667
5240
8090
35,339
9362
101,161
19,376
5733
17,839
29,498
13,806
38,764
8659
5312
4864
9921
5063
1044
21,768
3950
1778
47,459
26,535
9966
3392
1447
11,357
530
4877
593
238
895
2968
TOTAL PIPELINE MILEAGES
TRANSMISSION & DISTRIBUTION
OIL - GAS - PRODUCTS LINES
1953
PREPARED BY ELDON V. HUNT
CONSTRUCTION SUPERINTENDENT
EBASCO SERVICES INCORPORATED
2 RECTOR STREET
NEW YORK

Fig. 1

PROCEEDINGS-SEPARATES

The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

VOLUME 80 (1954)

FEBRUARY: 398(IR)[d], 399(SA)[d], 400(CO)[d], 401(SM)[c], 402(AT)[d], 403(AT)[d], 404(IR)[d], 405(PO)[d], 406(AT)[d], 407(SU)[d], 408(SU)[d], 409(WW)[d], 410(AT)[d], 411(SA)[d], 412(PO)[d], 413(HY)[d].

MARCH: 414(WW)[d], 415(SU)[d], 416(SM)[d], 417(SM)[d], 418(AT)[d], 419(SA)[d], 420(SA)[d], 421(AT)[d], 422(SA)[d], 423(CP)[d], 424(AT)[d], 425(SM)[d], 426(IR)[d], 427(WW)[d].

APRIL: 428(HY)[c], 429(EM)[c], 430(ST), 431(HY), 432(HY), 433(HY), 434(ST).

MAY: 435(SM), 436(CP)[c], 437(HY)[c], 438(HY), 439(HY), 440(ST), 441(ST), 442(SA), 443(SA).

JUNE: 444(SM)[e], 445(SM)[e], 446(ST)[e], 447(ST)[e], 448(ST)[e], 449(ST)[e], 450(ST)[e], 451(ST)[e], 452(SA)[e], 453(SA)[e], 454(SA)[e], 455(SA)[e], 456(SM)[e].

JULY: 457(AT), 458(AT), 459(AT)[c], 460(IR), 461(IR), 462(IR), 463(IR)[c], 464(PO), 465(PO)[c].

AUGUST: 466(HY), 467(HY), 468(ST), 469(ST), 470(ST), 471(SA), 472(SA), 473(SA), 474(SA), 475(SM), 476(SM), 477(SM), 478(SM)[c], 479(HY)[c], 480(ST)[c], 481(SA)[c], 482(HY), 483(HY).

SEPTEMBER: 484(ST), 485(ST), 486(ST), 487(CP)[c], 488(ST)[c], 489(HY), 490(HY), 491(HY)[c], 492(SA), 493(SA), 494(SA), 495(SA), 496(SA), 497(SA), 498(SA), 499(HW), 500(HW), 501(HW)[c], 502(WW), 503(WW), 504(WW)[c], 505(CO), 506(CO)[c], 507(CP), 508(CP), 509(CP), 510(CP), 511(CP).

OCTOBER: 512(SM), 513(SM), 514(SM), 515(SM), 516(SM), 517(PO), 518(SM)[c], 519(IR), 520(IR), 521(IR), 522(IR)[c], 523(AT)[c], 524(SU), 525(SU)[c], 526(EM), 527(EM), 528(EM), 529(EM), 530(EM)[c], 531(EM), 532(EM)[c], 533(PO).

NOVEMBER: 534(HY), 535(HY), 536(HY), 537(HY), 538(HY)[c], 539(ST), 540(ST), 541(ST), 542(ST), 543(ST), 544(ST), 545(SA), 546(SA), 547(SA), 548(SM), 549(SM), 550(SM), 551(SM), 552(SA), 553(SM)[c], 554(SA), 555(SA), 556(SA), 557(SA).

DECEMBER: 558(ST), 559(ST), 560(ST), 561(ST), 562(ST), 563(ST)[c], 564(HY), 565(HY), 566(HY), 567(HY), 568(HY)[c], 569(SM), 570(SM), 571(SM), 572(SM)[c], 573(SM)[c], 574(SU), 575(SU), 576(SU), 577(SU), 578(HY), 579(ST), 580(SU), 581(SU), 582(Index).

VOLUME 81 (1955)

JANUARY: 583(ST), 584(ST), 585(ST), 586(ST), 587(ST), 588(ST), 589(ST)[c], 590(SA), 591(SA), 592(SA), 593(SA), 594(SA), 595(SA)[c], 596(HW), 597(HW), 598(HW)[c], 599(CP), 600(CP), 601(CP), 602(CP), 603(CP), 604(EM), 605(EM), 606(EM)[c], 607(EM).

FEBRUARY: 608(WW), 609(WW), 610(WW), 611(WW), 612(WW), 613(WW), 614(WW), 615(WW), 616(WW), 617(IR), 618(IR), 619(IR), 620(IR), 621(IR)[c], 622(IR), 623(IR), 624(HY)[c], 625(HY), 626(HY), 627(HY), 628(HY), 629(HY), 630(HY), 631(HY), 632(CO), 633(CO).

c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

AMERICAN SOCIETY OF CIVIL ENGINEERS

OFFICERS FOR 1955

PRESIDENT

WILLIAM ROY GLIDDEN

VICE-PRESIDENTS

Term expires October, 1955:
ENOCH R. NEEDLES
MASON G. LOCKWOOD

Term expires October, 1956:
FRANK L. WEAVER
LOUIS R. HOWSON

DIRECTORS

Term expires October, 1955:
CHARLES B. MOLINEAUX
MERCEL J. SHELTON
A. A. K. BOOTH
CARL G. PAULSEN
LLOYD D. KNAPP
GLENN W. HOLCOMB
FRANCIS M. DAWSON

Term expires October, 1956:
WILLIAM S. LaLONDE, JR.
OLIVER W. HARTWELL
THOMAS C. SHEDD
SAMUEL B. MORRIS
ERNEST W. CARLTON
RAYMOND F. DAWSON

Term expires October, 1957:
JEWELL M. GARRELTS
FREDERICK H. PAULSON
GEORGE S. RICHARDSON
DON M. CORBETT
GRAHAM P. WILLOUGHBY
LAWRENCE A. ELSENER

PAST-PRESIDENTS

Members of the Board

WALTER L. HUBER
DANIEL V. TERRELL

EXECUTIVE SECRETARY

WILLIAM N. CAREY

ASSISTANT SECRETARY

E. L. CHANDLER

TREASURER

CHARLES E. TROUT

ASSOCIATE SECRETARY

WILLIAM H. WISELY

ASSISTANT TREASURER

CARLTON S. PROCTOR

PROCEEDINGS OF THE SOCIETY

HAROLD T. LARSEN
Manager of Technical Publications

DEFOREST A. MATTESON, JR.
Editor of Technical Publications

PAUL A. PARISI
Assoc. Editor of Technical Publications

COMMITTEE ON PUBLICATIONS

SAMUEL B. MORRIS, *Chairman*

JEWELL M. GARRELTS, *Vice-Chairman*

GLENN W. HOLCOMB
OLIVER W. HARTWELL
ERNEST W. CARLTON
DON M. CORBETT